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# Managing environmental risk in agriculture: a systematic perspective on the potential of quantitative policy-oriented risk valuation

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## Abstract

This paper seeks to offer a systematic overview of methods and techniques for environmental quality degradation, with a particular view to the management of agricultural risk, against the background of policy relevance. The paper argues that modern valuation methods from ecological economics can play an important role in advancing transparent policy decisions, but at the same time the paper also warns against unjustified optimism. Consequently, also a systematic review of various caveats in evaluation methods is offered.

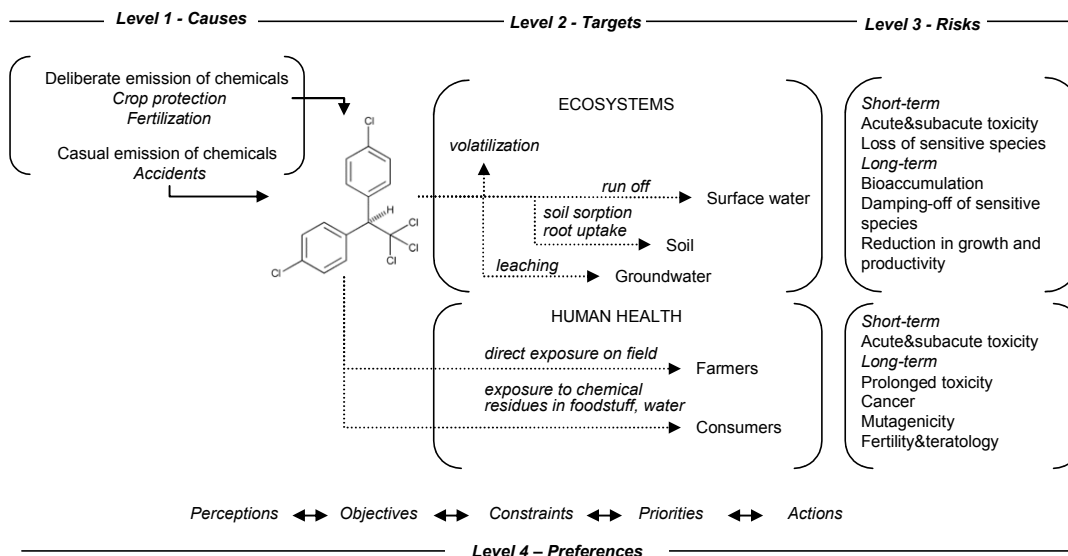
## 1. Introduction

Surface water, groundwater and soil contamination, reduced biodiversity related to the use of agrochemicals and harm to consumers exposed to dangerous residues and micro-organism in food are just a few examples of the number of negative externalities of modern agriculture. In such context what we observe is that, in the majority of cases, human pressure on natural and agro-ecosystems is the result of a systematic, deliberate and continuous pursuit of wealth by business, individuals and communities, rather than the effect of random events. It is therefore desirable that the problem of how to deal with the drawbacks of modern agricultural development should also be approached with systematic, deliberate, and continuous strategies at different administrative and spatial levels. But how?

This paper reviews the contribution that environmental valuation can offer in order to effectively enhance environmental risk management. Issues, challenges, alternative valuation methods and their potential for risk management are discussed, and illustrated with a specific view to the case of agrochemical risk valuation.

## 2. Issues in Environmental Risk Management

Environmental risk management is essentially concerned with the management of interactions between natural or artefact ecosystems, societies and economies. Interactions are both physical and non-physical and, by definition, they are characterized by complexity. Figure 1 illustrates the main degrees of complexity to be taken into account in agricultural risk management, assuming agrochemicals (i.e. fertilizers and pesticides) as the main source of risk.



**Figure 1: Drivers of complexity in agrochemical risk management**

At a first level, complexity is manifest in the variety of causes that can drive environmental impoverishment and its negative effects on ecosystems and their communities in an agricultural area. At a second level, complexity reflects the range of ecological and human populations exposed to risk of damage, as risk targets and the involved stakeholders can vary substantially depending on the pattern of chemical diffusion in the environment. Thirdly, it concerns spatial and time scales, since risk can be macroscopically detectable starting from the very beginning (e.g. acute intoxication), or become manifest after a certain period of latency (e.g. cancer risk). Similarly, risk can spread over space to different degrees according to global and local systemic conditions resulting in local, regional or global contamination (e.g. Persistent Organic Pollutants, POPs). Finally, at a fourth level, it concerns personal, societal and decision makers' preferences that contribute to set the reference framework according to which we can analyse risks, set priorities, propose management actions and produce sound evaluations.

Each of the aforementioned facets of complexity needs to be addressed systematically within the process of risk management. Multiple, complementary and specific research inputs are therefore needed to identify policy actions able to manage and reduce risks to their minimum.

### 3. Need for quantitative policy-oriented research

#### 3.1. The role of valuation

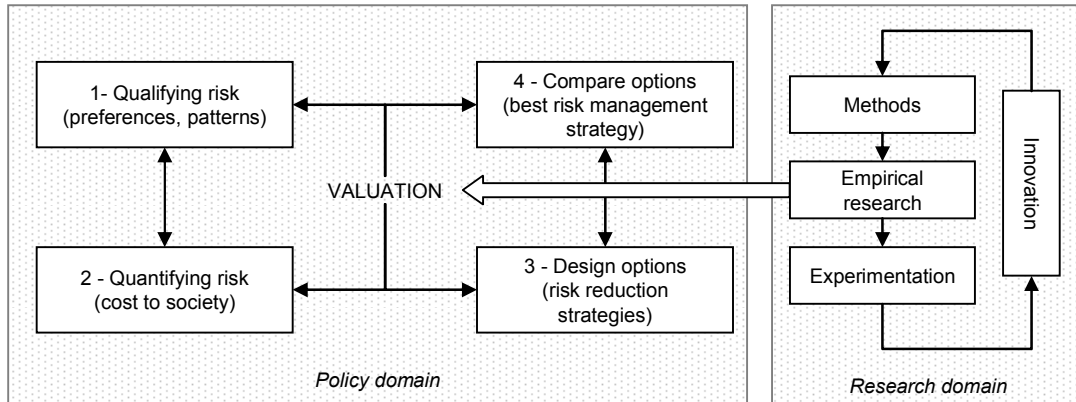
Among the range of tools for environmental analysis available to researchers, environmental valuation can provide a valuable contribution in order to finalise the risk management process. Under the policy domain (see Figure 2: left-hand side), valuation can act as a tool to:

1. Qualify risk: on the basis of risk assessment's results<sup>1</sup>, analyse risk preferences and risk patterns in agricultural production.
2. Quantify risk: provide a measurement of the costs and benefits involved, giving a quantitative monetary estimation of the risks to ecosystems and humans.

<sup>1</sup> A physical quantification of risk.

3. Design options: design policy options to contain or manage risk, thus offering a range of possible solutions.
4. Compare options: select the policy option expected to provide the best result in reducing risk.

Valuation itself therefore represents a systematic and structured approach to appraising the risks and the options designed to manage them on the basis of the costing methodology.



**Figure 2: The role of economic valuation in environmental risk management**

Under the research domain (see Figure 2: right-hand side), depending on the issue at stake, research efforts might be oriented in different directions, as they might draw from different methodological approaches available to value the risk: for instance, conventional market-based costing-techniques, or non-market valuation methods (revealed and stated preference methods). Similarly, different techniques for options appraisal are likely to be employed (e.g. cost-benefit analysis, cost-effectiveness analysis, multicriteria analysis).

In principle, we can however recommend that it is necessary to look for an optimal context-specific framework of environmental valuation supported with substantive and causal scientific investigation. Operational analysis needs to be strategic in nature and should be supported by a proper – preferably quantitative – methodology for the systematic evaluation of the analytical knowledge available. In this perspective what is evident is that there is still a need for more context-specific research, which entails considerable effort. In agriculture risk management, more empirical primary studies on the valuation of environmental risk are needed to: i) allow methodological innovation based on experimentation; and ii) produce a sound body of knowledge to be used for research synthesis.

### 3.2. Pricing agricultural risk

In agricultural risk management, the research challenges emerge from the policy arena and are intended to provide support to relevant policy issues such as: Which agriculture-induced risks should be prioritised? Which management or mitigation options should be chosen to respond to these risks? And how far it is necessary to go in, for instance, reducing agrochemical use? Is action preferable to the do-nothing scenario? For rational choices on the allocation of public or private resources to the improvement of sustainability in the context of agricultural land use, a trade-off between the costs and benefits of available alternative policy strategies needs to be made<sup>2</sup>.

Decision makers can be supported by the results of environmental valuation performed in two stages of making agricultural risk management decisions:

<sup>2</sup> Even though the marginal costs of improving the marginal benefits are not directly observable.

- Stage 1 - Assessment, prioritisation, and ranking of risks and impacts: to generate robust order-of-magnitude estimates of the cost of agriculture externalities, so that their relative importance can be established.
- Stage 2 - Management options appraisal: to generate valid order-of-magnitude estimates of the net benefits of management strategies for tackling specific environmental risks.

In Stage 1, the role of environmental valuation is to estimate the economic value of a given agrochemical risk in the absence of management strategies. The reference scenario would be defined by the ongoing status quo situation, in a given geographical and temporal context, in the absence of policy actions to manage the risk. When analysing future events, more realism might also be introduced by constructing projections of future natural, environmental and socio-economic conditions in the study region, in the absence of mitigation or risk management strategies. The value of this information is that it reveals to decision makers those risks that are likely to cause the most severe damage and, thus, those risks to which most attention should be given.

In Stage 2, we assume that decision makers can undertake some form of action in response to important agricultural risks to ecosystems and human health. The expected effect of the policy intervention is to reduce the future exposure of a receptor to the risk concerned. We can think of the degree of risk reduction as the effectiveness of the policy response, or the gross benefits of acting against risk. This is given by the estimated impact of a given environmental risk in the absence of policy actions, minus the estimated impact with risk management (i.e. policy intervention). In such a management decision context, environmental valuation can be used to estimate the gross monetary benefit of a management strategy. This information allows the decision maker to accept or reject a single management policy strategy, or to choose one strategy out of a number of possibilities.

Sound valuation methods are required in both the aforementioned stages in making agricultural risk management decisions. However, the most suited valuation methodological approach will need to be identified with a retrospective look at the well-known debate on the best valuation paradigm to be applied for policy-making support.

### **3.3. Which valuation paradigm do we need?**

In common usage, the term *value* means relevance or desirability. It is clear, however, that the transfer between general usage and each discipline's perspective on how relevance or desirability should be gauged has stimulated considerable debate among ecologists, economists, and philosophers (e.g. O'Riordan, 1976; Blamey and Common, 2000). From alternative conceptions of what environmental value is, in fact, different notions of sustainability and environmental quality can be derived, each of which is expected to influence policy aims, valuation tools and instruments for proper risk management (for a discussion see, e.g., Turner, 2000).

The present paper takes the stance that the 'anthropocentric' (e.g. see Blamey and Common, 2000) and 'non-anthropocentric' (e.g. O'Riordan, 1976; Goodpaster, 1978; Watson, 1979; Rollston, 1988) valuation paradigms are complementary rather than competing valuation models (see: Spash, 2000; Bateman et al., 2003). The debate on the notion of sustainability and risk evaluation in fact cannot be separated from the purpose for which it is required, and from the context in which it takes place (for a discussion see, e.g., Norton, 1995; Turner, 2000). So, for instance, the 'anthropocentric' monetary valuation of risk offers a foundation for Pigouvian taxation schemes in agricultural risk management, as well as for the design of incentive schemes for low-input agricultural practices (e.g. see Ekins, 1999). Similarly, Cost-Benefit Analysis (CBA) is recommended for ex ante and ex post environmental policies appraisal, as well as whenever it is necessary to choose among alternative environmental management plans with some budget constraints (see, e.g. Pearce and Seccombe-Hett, 2000).

Likewise, there are a number of situations that entail going beyond the neoclassical cost-benefit perspective without rejecting the usefulness of preference-based values. A revision of CBA principles applies, for instance, for high uncertainty irreversible problems, e.g. Genetically Modified Organisms (GMOs) or Persistent Organic Pollutants (POPs). This field may therefore pertain to multiple objective programming models, or multicriteria analysis for quantitative, qualitative or fuzzy information (see Nijkamp, 2000).

#### **4. Valuation Methodologies in Comparison**

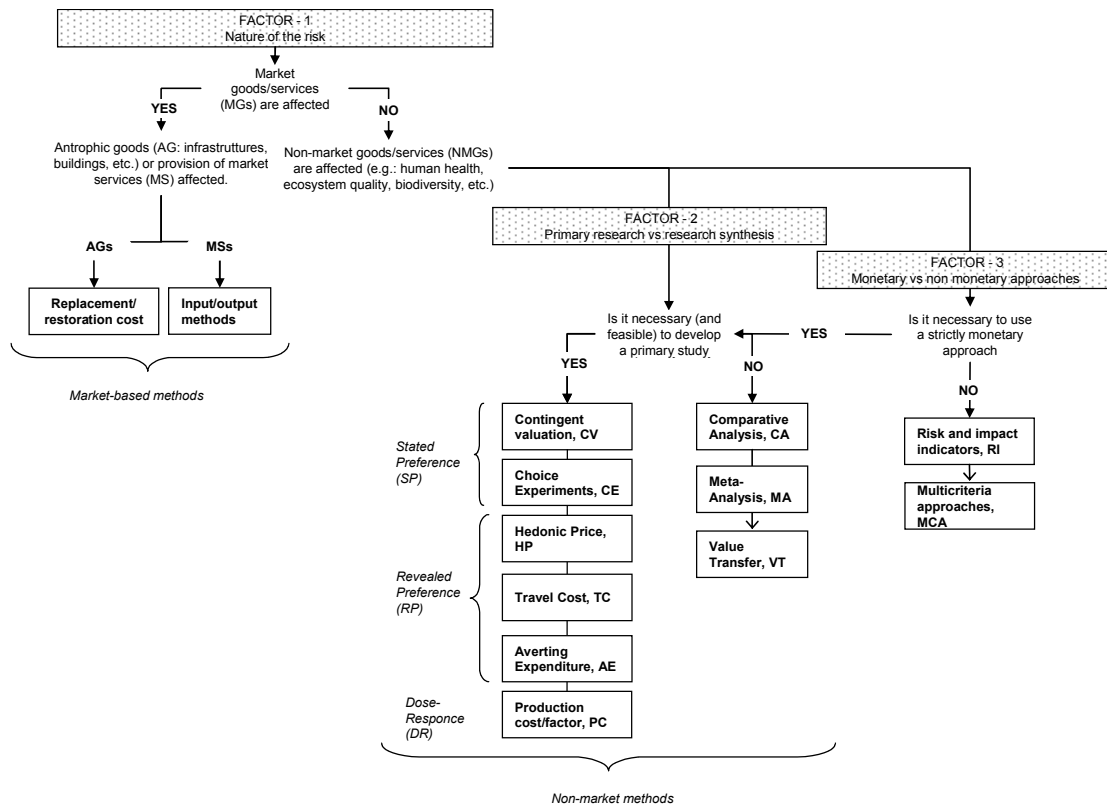
##### **4.1. How to select the preferred valuation approach?**

According to the previous discussion, several valuation approaches can be adopted to value environmental externalities due to agriculture. Taking a step further from the debate on the moral and theoretical foundations of the notion of total economic value and the related valuation paradigms, in practice, the selection of the preferred valuation method rests on a restricted number of factors that we illustrate in Figure 3 and discuss below.

##### *FACTOR 1 - NATURE OF THE RISK*

A first element to be considered is related to the nature of the good being affected by the risk/impact of concern. In particular, one can make a distinction between goods or services exchanged in regular markets, the 'market goods', and goods/services that are not sold and bought in regular markets, the 'non-market goods'. Clearly, most of the environmental risks generated by agriculture that are considered in this study belong, by definition, to the latter category. For instance, reduced water quality caused by pesticide use and risk to biodiversity are non-market goods.

In Figure 3, this distinction leads either to market (also called non-preference) or non-market (preference) valuation methods. Following such a choice factor, when focusing on environmental and human health risks, we enter the right side of the diagram on non-market valuation methods. Conversely, if pure financial external costs are addressed, then the valuation framework typically relies on an estimation of the actual expenditures which society incurs in dealing with those market externalities. This approach does not, therefore, actually value the externality, but uses as a proxy the expenditure which society incurs in dealing with that externality (Hanley and Oglethorpe, 1999; Hill and Crabtree, 2000). The range of impacts that can be evaluated is limited, but it can help to provide estimates of use values, as well as overcome the problem of scientific uncertainty where the expenditure is incurred in relation to a specific agricultural issue. Among the other, a recent study by Pretty et al. (2000) assessed the negative externalities of UK agriculture on the basis of treatment and prevention costs (i.e. costs incurred to clean up the environment and restore human health to comply with legislation or to return them to a pristine state) and administration and monitoring costs (i.e. costs incurred by public authorities and agencies to monitoring environmental, food and health parameters).



**Figure 3: Relevant factors for selecting the preferred valuation method**

**Note:** Modified from Metroeconomica, 2004.

#### *FACTOR 2 - PRIMARY RESEARCH VS RESEARCH SYNTHESIS*

A second choice element concerns the possibility of undertaking an original primary study, or not. As already stated, in fact, sometimes suitable economic valuation techniques will not be applicable due to time and budget constraints. Likewise, before undertaking a costly primary study, an in-depth literature review might be strongly required in order to better orient the empirical work. In such circumstances, the use of research synthesis methods (such as comparative analysis and meta-analysis) and value transfer techniques might be conveniently employed. Next, if a primary valuation study is needed, researchers can rely either on direct (Stated Preference, SP) or indirect (Revealed Preference, RP) valuation methods, or on the Dose-Response Methods (DR). Depending on the issue at stake, the advantages and disadvantages of Stated Preference versus Revealed Preference and Dose Response methods will be compared and the best valuation methodology selected.

#### *FACTOR 3 - MONETARY VS NON MONETARY APPROACHES*

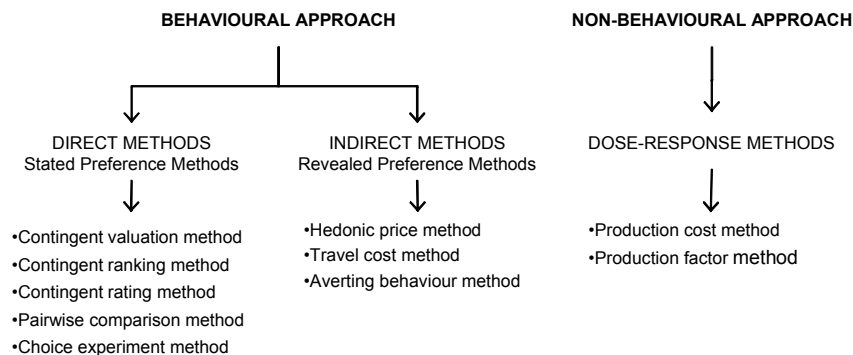
Finally, a third question is whether it is essential and relevant to employ a strictly monetary valuation approach. Some agriculture risks, such as the environmental and human health risks due to agrochemicals' mixture, have not hitherto been physically quantified, so any attempt of monetization would most probably lead to unreliable results. Sometimes, the environmental value quantification in monetary terms might raise ethical objections, and technocratic solutions be advocated (see Suter, 1995). Similarly, sometimes, in order to reach a shared consensus on the preferred risk management strategy, the decision making process rests also on criteria other than mere economic efficiency, e.g. social equity and environmental quality. In these cases, risk or impact indexes might be designed to qualify or quantify the environmental external cost, although

not in monetary terms, and be employed within a multicriteria framework of analysis for risk management options appraisal.

The following sections provide more details on the three previously discussed choice elements.

## 4.2. Primary monetary valuation research

As illustrated in Figure 3, various valuation methods are available to put a monetary value on the environmental impact of agriculture, and a number of classifications of the valuation methods have been proposed (Pearce and Markandya, 1989; Mitchell and Carson, 1989; Nunes, 2002). We distinguish three groups of valuation methods: the Stated Preference (SP), the Revealed Preference (RP) and the Dose-Response (DR) methods (see Figure 4).



**Figure 4: A classification of valuation methods**

The Stated Preference and Revealed Preference valuation methods have in common that they reveal people's preferences – either directly or indirectly – with a behavioural-linkage approach through hypothetical markets (Mitchell and Carson, 1989). The value of agricultural goods and services would therefore be represented to an extent by people's willingness-to-pay (WTP) for them, and this would allow the estimation of lost benefits, i.e. the correct economic welfare measure.

Conversely, the Dose Response methods have in common that they put a price on environmental commodities, without retrieving people's preference for these commodities (Nunes, 2002). The production cost techniques, for instance, calculate the monetary value of the negative effects of, say, soil pollution of nutrients and chemicals, by using a production cost technique and multiplying the increased maintenance and repair prices (Feenstra, 1984). Another example of the dose-response method is when researchers use the production factor approach to estimate, for instance, the economic value of cleaner soil by means of the increased agricultural output by using a demand and supply model (Smith, 1991).

### *REVEALED PREFERENCE*

This valuation method consists of three techniques: the Hedonic Price (HP) method; the Travel Cost (TC) method (see Bockstael et al., 1991); and the Averting Behaviour (AB) method (see Branden and Kolstad, 1991). The common underlying feature is a dependency on the relationship between a market good and the environmental commodity to be valued (Nunes, 2002). Among the other, we are aware of hedonic studies estimating the external costs of pesticides (Söderqvist (1994 and 1998; Beach and Carlson 1993).

### *STATED PREFERENCE*

The group of Stated Preference valuation methods all rely on survey methods to directly infer people's preferences for a given environmental commodity. The underlying feature is the use of ad hoc questionnaires to ask the individuals to directly state their economic values for environmental commodities (e.g. see Mitchell and Carson, 1989). However, this method has a number of different



versions, such as Contingent Valuation (CV), Contingent Ranking (CRk), Contingent Rating (CRT), Choice Experiment (CE) and Pairwise Comparison (PC) (see Louviere et al., 2000). These variants of the survey method differ in the way in which the economic values are elicited (see Nunes, 2002).

Currently, an extensive empirical literature on agro-chemical risk valuation using Stated Preference techniques is available (for complete reviews of pesticide risk valuation literature see Travisi et al., 2006a; Florax et al. 2005). The WTP estimates provided in this literature refer to the effects of different types of risks, in particular to impacts on human health, and to damages to environmental agro-ecosystems. Because of the historically human-driven rather than environmentally-driven interest of agro-chemical risk management, economists too have been concentrating their efforts more on human rather than environmental consequences of agrochemical usage, and the literature therefore focuses primarily on the valuation of health effects on consumers and farmers (see, e.g., Pingali et al., 1994; Crissman et al., 1994; Antle and Pingali, 1994; Roosen et al., 1998; Thompson and Kidwell, 1998; Blend and van Ravenswaay, 1999; Fu and Hammitt, 1999; Wilson, 2002). Significantly fewer studies address the ecological dimension of agrochemical risk (see, e.g. Higley and Wintersteen, 1992; Mullen et al., 1997; Lohr et al., 1999; Foster and Mourato, 2000; Brethour and Weersink, 2001; Cuyno et al., 2001; Travisi and Nijkamp, 2004). But what can we learn from the abundance of results in the literature?

## 4.2. Research synthesis and value transfer

Environmental economists are increasingly relying on research synthesis techniques to infer monetary estimations of environmental goods on the basis of results of previously performed valuation studies. Research synthesis summarises, compares, integrates, and eventually extrapolates new insights from the results of primary and secondary analysis already available in the literature (see Cooper and Hedges, 1994). There may be various methods for research synthesis and comparison, and several commentators have made a strict distinction between comparative analysis and meta-analysis and narrative literature reviews (Glass, 1976; Cooper, 1998; Florax et al., 2002). Similarly to the classification by Button (2002), we distinguish three forms of research synthesis methodologies: literary reviews (LR); comparative analysis (CA); and meta-analysis (MA) (see Table 1).

**Table 1: A summary of research synthesis methods**

Technique	Information	Strengths ++	Weaknesses --
REVIEWS	<ul style="list-style-type: none"> <li>• Publications</li> <li>• Reports</li> <li>• Speeches</li> </ul>	<ul style="list-style-type: none"> <li>• Combine qualitative and quantitative information</li> <li>• Easy to comprehend</li> </ul>	<ul style="list-style-type: none"> <li>• Lack rigour</li> <li>• Subjective</li> </ul>
COMPARATIVE ANALYSIS	<ul style="list-style-type: none"> <li>• Publications</li> <li>• Reports</li> <li>• Speeches</li> <li>• Interviews</li> </ul>	<ul style="list-style-type: none"> <li>• Systematic approach</li> <li>• Up-to-date insights</li> <li>• Combine qualitative and quantitative information</li> <li>• Can look forward</li> </ul>	<ul style="list-style-type: none"> <li>• Lack statistical rigour</li> <li>• Subjective</li> <li>• Fads in expert opinion</li> </ul>
META-ANALYSIS	<ul style="list-style-type: none"> <li>• Publications</li> <li>• Reports</li> </ul>	<ul style="list-style-type: none"> <li>• Transparency</li> <li>• Systematic approach</li> <li>• Statistical basis</li> </ul>	<ul style="list-style-type: none"> <li>• Limited case material</li> <li>• Selectivity</li> <li>• Comparability of studies</li> <li>• Problems of quantification</li> </ul>

The longest established and most widely-used method for bringing together information from previous studies is the literary review, i.e. a written text, supplemented by illustrative data, in which findings of earlier studies are set out and compared, and judgements are made about the strength and quality of the various pieces of work being valued. A major problem of this traditional literary-type approach is that it tends to be qualitative and subjective, and therefore, lacks of rigour.

Conversely, quantitative comparative analysis and meta-analysis are systematic and quantitative in nature (Glass, 1976; Cooper, 1998; Florax et al., 2002), thus allowing to reduce the level of subjectivity typical of literary reviews (Florax et al., 2002; van den Bergh and Button, 1999), and to make their judgements more transparent (Button, 2002). Among these alternative methods for research synthesis meta-analysis (MA), in association with value transfer techniques, has gained a primary role for valuation purposes. Meta-analysis refers to the statistical analysis of a large collection of analysis results from individual studies, for the purpose of integrating research findings (Glass, 1976). It especially focuses on the comparison of the outcomes of previously-performed primary studies by means of statistical techniques (Cooper, 1998; Cooper and Hedges, 1994). In doing this, therefore, it may help to generate more clearly numerical monetary values of the costs and benefits of environmental risks from the available data, as well as helping to understand the robustness of willingness-to-pay (WTP) estimates by referring to research synthesis as a kind of sensitivity analysis. Finally, most appealing for valuation research is the possibility of using meta-analysis to transfer results of studies performed earlier to an unexplored policy setting, i.e. the value transfer (VT) approach<sup>3</sup> (Brouwer, 2000).

Environmental economic research has already contributed a great variety of meta-analytical studies (e.g.: Smith and Huang, 1995; van den Bergh et al., 1997; Button and Kerr, 1996; Button, 1995). In the context of agricultural risks, meta-analysis for tracing factors that are responsible for differing results across similar studies that estimate the WTP for reduced pesticide risk exposure, have been provided by Travisi et al. 2006a and Florax et al. 2005. However, the application of meta-analysis for agrochemical risk value transfer is still unexplored. In particular, for pesticide risk values, the results by Florax et al. 2005 reveal that it may still be too early for a meta-analysis to be able to provide a consistent and robust picture of the large range of WTP assessments across different target types (terrestrial and aquatic ecosystems, biodiversity, farmers, consumers, etc.). Given the intrinsic heterogeneity in effects of pesticide usage across different target types (food safety, health effects on farmers, and aquatic and terrestrial ecosystems), as well as across geographical space, and given the non-negligible impact of research designs on the estimated WTP values, more primary research on pesticide risk valuation is called for.

#### 4.4. Non-monetary valuation

Whenever a non-monetary valuation approach is the preferred option to value risks, a broad agreement is arising in the scientific community on the usefulness of indicators/indexes<sup>4</sup> as instruments capable of achieving a meaningful compromise between the demand for a sound scientific approach and the need for transparent public policy tools (OECD, 1997, 1999a). This evolution has been largely driven by increased public awareness of environmental issues, their domestic and international aspects and their linkages with economic and social issues. This has stimulated a number of national and international institutions, as well as researchers (e.g. Atkinson et al., 1997; Arrosson, 1997), to produce environmental information that is more responsive to policy needs and public information requirements. Their aim is to further strengthen the capacity of nations to monitor and assess environmental conditions and trends so as to increase their accountability and to evaluate how well they are satisfying their domestic objectives and

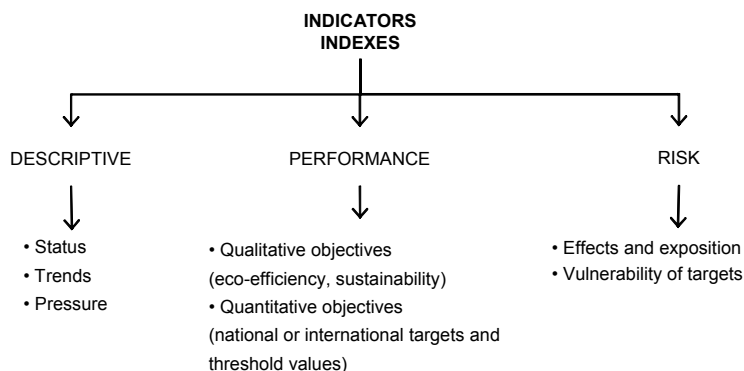
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<sup>3</sup> VT (or benefit transfer, BT) is commonly defined as the transposition of monetary environmental values estimated at one site (named the 'study site') through market-based or non-market based economic valuation techniques to another site (named the 'policy site'). Three main types of VT can be distinguished: a) simple transfer of a mean effect size (for instance a WTP estimate); b) transfer of a demand or bid function (i.e. benefit function transfer); and c) transfer of an estimate based on meta-analysis (Florax et al., 2002).

<sup>4</sup> Generally speaking, an indicator can be defined as a parameter, or a value derived from parameters, which points to, provides information about, and describes the state of a phenomenon/environment/area, with a significance extending beyond that directly associated with a parameter value. An index is, instead, a set of aggregated or weighted parameters or indicators.

international commitments. In this context, environmental indicators are cost-effective and valuable tools. Several classifications of the different types of indicators/indexes are available (e.g. OECD, 1999a). We propose a classification that distinguishes four classes of indicators/indexes (see Figure 5): i) descriptive indicators/indexes; ii) performance indicators linked to qualitative objectives (aims, goals); iii) performance indicators linked to quantitative objectives (targets, commitments); and iv) risk indicators.

Descriptive indicators can be *status* or *trend* ones, i.e. they provide a picture of the current status (or trend) of a given environmental phenomenon, usually in terms of pressure, e.g. air emission levels/trend, surface and groundwater quality, quantities of agrochemical applied on fields, and so forth. Performance indicators linked to qualitative objectives generally address the concept of performance in two ways: a) with respect to the eco-efficiency of human activities, e.g. chemical application per unit of production or relative trends of waste generation and GDP growth; and b) with respect to the sustainability of natural resource use, e.g. the intensity of use of rural resources, intensity of the use of water resource, etc. *performance* indicators/indexes with reference to quantitative objectives address the concept of performance with respect to national or international targets or threshold values set by regulation, e.g. agrochemical use levels/trends relating to national or international targets, water quality relating to national standards, level of pesticide residues in food relating to health threshold levels, etc. Further types are *risk* indicators/indexes, which are designed on the basis of the information required within environmental risk assessment procedures (see e.g. Finizio et al., 2001).



**Figure 5: A classification of types of environmental indicators**

In particular, in the case of agrochemical risk valuation, the lively debate on the design of risk indicators is based on the stance of their complementarities to more consolidated and standardised procedures, such as risk assessment and registration (OECD, 1996). Depending on the environmental risk concerned (chemical risk, hydrogeological risk, etc.), the information required to implement the risk indicators will vary. Usually, risk indicators integrate data and information on the potential effects of an agrochemical, or their likelihood, with some information on the vulnerability of the environmental system or population exposed to it. For instance, on a first level of assessment, risk indicators may be designed as instruments for predictive risk management approaches, to offer preliminary insights into the *status quo* of environmental risks. They may be developed to obtain baseline information about agrochemical use and risks, focusing on one or more realistic hazardous scenarios, and they may assist the identification of potential *trouble spots* and *vulnerable areas* where risk reduction might be necessary (see Travisi et al., 2006b).

## 5. Synthesis and Conclusion

Economists have tried to quantify agricultural risks by establishing, *inter alia*, measurements based on the well-known concept of *willingness-to-pay*, and a number of quantification techniques are available (for reviews on agrochemical risk valuation, see Travisi et al., 2006a and Florax et al., 2005). Nevertheless, the process of quantification raises several objections and presents challenging research issues. For agricultural land use risks, for instance, quantitative data on some physical impacts might not be available, so that it will be not possible (or not straightforward) to put a monetary value on the impact. This is the case for agriculture-driven marine eutrophication and poisoning of domestic pets (see Pretty et al., 2000). For other impacts, such as the cost of returning the environment and human health to pristine conditions, suitable economic valuation techniques will not be applicable because of time and budget constraints. Sometimes, environmental value quantification might raise ethical objections, and technocratic or ‘deep ecology’ (Singer, 1979) solutions may be advocated, as in the case of mortality and cancer risk evaluation. Yet, for a complete assessment, all the significant impacts must be incorporated into the decision-making process (or a discussion: Pretty et al., 2001). Therefore, a methodological approach flexible enough to be applied across a range of impacts and scales – from broad aggregated impacts on a region down to very refined disaggregated impacts on a particular target receptor – needs to be adopted. In this paper, by providing a thorough assessment framework in which several quantitative techniques of environmental valuation can be alternatively applied, we tried to offer a comprehensive picture of the major virtues, obstacles, and challenges of the economic valuation of environmental decay for policy advice, taking agrochemical risk as an example.

Now, we offer a qualitative systematic comparative assessment of alternative valuation methods taking into account various policy applications. The specific evaluations on each policy dimension draw directly from qualitative and quantitative insights documented in Section 3 and 4, dealing with research requirements, policy potential, and attractiveness for policy use.

In Table 2, each entry shows the potential contribution of different methods for the main possible policy uses identified, and whether they fulfil some standards that are expected to influence their attractiveness for policy application. In particular, we consider their role for the following policy applications:

1A - CBA of policies/projects Pricing policy

2A - Eco-taxes

3A - National accounts

4A - Management tool

5A - Participatory exercise

6A - Pressure/ risk assessment

and the following additional criteria:

1B - research effort required (in terms of intellectual, time, and monetary effort); 2B - flexibility of the assessment process (i.e. possibility of feedback and ‘trial and error’ processes, etc.);

3B - theoretical robustness versus practical usefulness;

4B - scientific rigour versus ease of comprehending the results (i.e. whether the approaches are user-friendly or not).

According to Table 2, no method scores best on all policy criteria.

CBA of projects is the traditional role of environmental valuation, and it remains the context in which Stated (and Revealed) preference methods are most used in Europe today (Hanley, 2000). However, recently, changes in EU legislation which mandate some form of environmental appraisal for new policies (e.g. Environmental Impact Assessment, Strategic Impact Assessment, etc.) have increased the usefulness of Stated Preference methods within CBA of policies. Furthermore, in the design of pricing policies, for instance, for access to and maintenance of natural resources such as national parks, valuation may be used to elicit the demand curve for the resource and to predict the effect of pricing on behaviour. This connection here arises, because

Stated Preference methods involve seeking the consumer's WTP for the asset. Also, certain techniques, namely, Choice Experiments, allow an estimation of the value of different attributes of the resource in question, enabling resources to be directed most efficiently to maintaining those particular assets. Stated Preference techniques might also be applied for designing eco-taxes whereby polluters (for instance, farmers) are charged directly for emitting pollutants. Most of the time these environmental taxes are calculated on the basis of political factors unrelated to their optimal design from an economic point of view. Nonetheless, there is now an increasing trend towards designing taxes so that they reflect the monetary value of the extra damage caused by 1 extra unit of pollution (Ekins, 1999; Pearce and Seccombe-Hett, 2000). This represents an adherence to a general rule for tax design derived from the theory of environmental economics. Much attention has recently indeed been focused on the implementation of taxes in agriculture (e.g. EEA, 1999; Jassen and Stryg, 1996). In Europe, pesticide taxes have been applied in Denmark, Finland, Sweden; fertilizer taxes in Austria (1986-94), Finland (1976-94), Sweden; and manure charges in Belgium and the Netherlands (Pretty et al. 2001). Moreover, we are witnessing a growing interest in modifying the "national accounts", i.e. the set of accounts that comprise a nation's gross national product (GNP), by also internalising the value of natural stocks and their depreciation due to pollution or other environmental risks<sup>5</sup>. This practice is usually referred to as "green accounting" (e.g. see Bartelmus, 1999; Turner and Tschirhart, 1999).

All the previously discussed policy purposes might, to some extent, be addressed by research synthesis techniques, namely, meta-analysis and value transfer. These, as said, are techniques that might be used as an alternative to stated preference methods (whenever a suitable body of literature is available) to provide monetary estimations of changes in natural stocks and environmental conditions. Compared with Stated Preference methods, however, meta-analysis and value transfer are generally more appealing to policy makers since they might provide quantitative policy advice at low cost. To be fair, however, the considerable research effort required for their application is relevant. The literature retrieval process and the data analysis can be extremely time-consuming, and the robustness of results is not always satisfactory (e.g. Brouwer and Spaninks, 1999). In addition, meta-analysis and value transfer rely on the body of knowledge coming from previously performed studies. Therefore, they do not allow much flexibility in the assessment process. In some cases, for instance, there might be considerable differences in the assets analysed in the literature compared with the new asset of concern, and some compromises may be required. Instead, the major value added of research synthesis comes from its ability to provide statistically robust comparisons of literature results and a systematic framework for establishing 'true' values of environmental goods and services.

Less well understood is the role that monetary valuation (provided with SP techniques) could play in asset management. Valuation indicates the relative strength of willingness-to-pay (WTP) for different features of a given asset. Hence, the asset could be managed so as to highlight and expand those features that attract the highest WTP. On the other hand, the contribution of indicators of pressure and risk as management tools appears to be better established. Environmental indicators are currently widely used in environmental reporting, measuring of environmental performance, and monitoring the effects of sectoral policies (transport, agricultural, etc.) and their sustainability. Their capacity to synthesise a vast amount of information in a user-friendly way represents their major comparative advantage for policy applications. In this concern, there is an emerging literature on the use of indicators to measure progress towards sustainability in agriculture (Bailey et al., 1999; OECD, 1999b; MAFF, 2000). Besides, recently, risk indicators based on sound ecotoxicological risk information have been designed in order to envisage possible future

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<sup>5</sup> GNP measures the total flow of goods and services in the economy. Some of this economic activity is taken up with replacing depreciation of assets such as machinery and roads. Hence, only the net national product contributes to average well-being. By the same token, such net measures do not include any depreciation of environmental assets such as coastal zones, rivers, forests, etc. Deducting the monetary value of the damage to the natural assets from the net national product would give a better measure of the "true" level of economic activity.

environmental risk scenarios, which draw plausible visions of future environmental conditions (see Travisi et al. 2006b). In addition, they are appropriate to be used within multicriteria (MCA) approaches (Jassen and Munda, 2000).

Finally, Stated Preference techniques and (often) multicriteria analysis involve a direct questionnaire approach that allows people to express preferences for or against environmental changes. In addition to the derivation of monetary values for the proposed changes, public participation can help to ensure that the final decision is acceptable to those who are likely to be most affected by it. Valuation also indicates gains and losses to different stakeholders, so that the likelihood for trades between gainers and losers can be identified and managed.

**Table 2: Methods of economic environmental analysis and effectiveness for policy making**

<i>Method</i>	<i>A - Potential for policy use</i>						<i>B - Attractiveness for policy use</i>			
	1A - CBA of policies/projects Pricing policy	2A - Eco-taxes	3A - National accounts	4A - Management tool	5A - Participatory exercise	6A - Pressure/risk assessment	1B - Research effort	2B - Flexibility of assessment process	3B -Theoretical robustness vs practical usefulness	4B - Scientific rigour vs ease of comprehension
<i>Stated preference</i>	+++	+++	+++	++	++	±	+++	±	+++	++
<i>Research synthesis</i>	++	++	++	±	±	±	+++	±	++	++
<i>Risk/Impact indicators</i>	±	±	++	+++	+++	+++	++	+++	+++	+++

**Note:** ‘+++’ denotes strong; ‘++’ denotes mild; ‘±’ denotes weak.

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